Renormalization group analysis of nuclear current operators

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We review our study of the Wilsonian renormalization group (WRG) analysis for nuclear current operators. We apply WRG method to axial-current operators derived from various approaches and obtain the unique effective low-energy operator.

Keywords: renormalization group; effective field theory; few-nucleon system

In Wilsonian renormalization group (WRG) analysis, one integrates out high-energy modes and examines the evolution of interactions. We apply the WRG analysis to nuclear operators such as nuclear potentials and current operators. It is known that various nuclear potentials equally well reproduce all of the data below the pion production threshold, while they appear quite different in describing the short range part. As a result of the model-space reduction using WRG equation, all the potentials converge to a single effective low-momentum potential.[1] Moreover, a parameterization of the single potential becomes the NEFT-based operator which, by construction, does not depend on modeling the small scale physics.

In evaluating an amplitude of an electroweak process in few-nucleon system, nuclear current operators are necessary ingredients as well as the nuclear force. The current operators based on different approaches have quite different behaviors in the short-range part, however, all of them give essentially the same reaction rates for low-energy reactions, *e.g.*, solar-neutrino reactions on the deuteron.[2] This implies that we can obtain a single effective current operator through the WRG analysis.

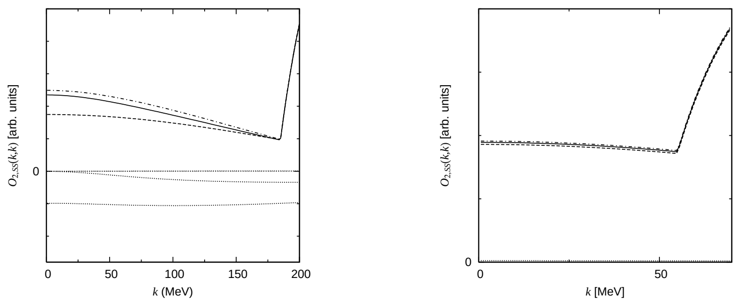

Fig. 1. Effective two-body current operators for initial S- to final S-wave state evaluated with the cutoff $\Lambda = 200$ MeV (left panel) and 70 MeV (right panel).

We derive a WRG equation for the current operator and use it to reduce the model space of currents from the models or NEFT with the pion (EFT(π)).[3] We are specifically concerned with the exchange axial-current operators relevant to the solar neutrino-induced breakup of the deuteron.

In Fig. 1, by reducing the model space, we find evolution of the bare two-body operators (lower three curves) to the effective ones (upper three ones). However, a model dependence still remains among the effective operators at $\Lambda = 200$ MeV (left panel). This is because even the one-pion range mechanism is model dependent. These effective currents are further evolved up to $\Lambda = 70$ MeV (right panel). With this resolution of the system, the model dependence among the currents is not seen any more, and thus we obtain the unique effective operator.

Furthermore, we simulate the effective two-body current with $\Lambda = 70$ MeV using the EFT($\not\pi$)-based parameterization. Except for "jump-up" structures in Fig. 1 due to the bare one-body current contribution, the two-parameter fit yields an almost perfect simulation. Therefore, one can obtain the EFT($\not\pi$)-based operator from the models or EFT(π) in this way.

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References

1. S.X. Nakamura, Prog. Theor. Phys. **114**, 77 (2005); M.C. Birse *et al.*, Phys. Lett. B **464**, 169 (1999); S.K. Bogner *et al.*, Phys. Lett. B **576**, 265 (2003).
2. M. Butler *et al.*, Phys. Rev. C 63, 035501 (2001); S. Nakamura *et al.*, Nucl.Phys. A 707, 561 (2002); S. Ando *et al.*, Phys. Lett. B 555, 49 (2003).
3. S.X. Nakamura and S. Ando, Phys. Rev. C **74**, 034004 (2006).